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Research Institute in Management Sciences

Solvay
Business School

Antecedents of Patenting Activity of European Universities

E. Sapsalis, B. Van Looy, B. van Pottelsberghe de la Potterie, J. Callaert and K. Debackere

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Université Libre de Bruxelles – Solvay Business School – Centre Emile Bernheim
ULB CP 145/01 50, avenue F.D. Roosevelt 1050 Brussels – BELGIUM
e-mail: ceb@admin.ulb.ac.be Tel. : +32 (0)2/650.48.64 Fax : +32 (0)2/650.41.88

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Elefthérios SAPSALIS[α] , Bart VAN LOOY[2 3], Bruno VAN POTTELSBERGHE DE LA POTTERIE[β], Julie CALLAERT[2], Koen DEBACKERE[2 3]

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Contact:
Elefthérios SAPSALIS: esapsali@ulb.ac.be
Bart VAN LOOY: bart.vanlooy@econ.kuleuven.be

[α] FNRS Research Fellow, Université Libre de Bruxelles - Solvay Business School – Centre Emile Bernheim, ULB, 50 Av. FD Roosevelt CP145/1, 1050 Brussels, BELGIUM, E-mail: esapsali@ulb.ac.be
[β] European Patent Office – Erhardtstr. 27; 80298 München (Germany); Université Libre de Bruxelles, Solvay Business School – Centre Emile Bernheim, DULBEA and CEPR, E-mail: bruno.vanpottelsberghe@ulb.ac.be
[2] Managerial Economics, Strategy and Innovation, Faculty of Economics and Applied Economics, Research Division INCENTIM, K.U.Leuven, Belgium, Naamse Straat 69, 3000 Leuven, BELGIUM. E-mail: bart.vanlooy@econ.kuleuven.be; Julie.callaert@econ.kuleuven.be.
[3] Steunpunt O&O Indicatoren, Faculty of Economics and Applied Economics, Dekenstraat 3, B-3000 Leuven, E-mail: koenraad.debackere@econ.kuleuven.be

Antecedents of Patenting Activity of European Universities:

Abstract: This paper analyzes antecedents of patent activity of 87 European universities. The findings reveal that more patent activity is observed within larger universities and at universities that encompass engineering and biomedical departments. Higher levels of scientific productivity and contract research coincide with higher levels of patent activity. The findings reveal that academic patenting is contingent on the combined effect of a scientific and entrepreneurial orientation of universities.

1. Introduction

Nowadays most universities embrace an entrepreneurial orientation complementing traditional teaching and research activities with activities aimed at translating scientific knowledge faster into economical application. A multitude of elements (see Powers, 2004) contributed to the growth of this 'entrepreneurial' phenomenon; which, at least in the US should be seen as a logical extension of the successful engagement of university research in fields such as space, defence and energy during the 1940s, 50s and 60s[1]. In the 1970s, this trend got yet another impetus by the 1973 discovery, by Cohen and Boyer, of a recombinant DNA technique by which a section of DNA was cut from the plasmid of an E.coli bacterium and transferred into the DNA of another. This discovery resulted in the invention of several patents that marked the onset of the modern biotechnology industry, ever since deeply rooted within academic research (Bud, 1994). This growing entrepreneurial orientation coincides with a renewed interest in the role universities can play within innovation systems (Nelson, 1993; Porter, 1995, Baumol, 2004) especially within emerging, knowledge intensive, economical activities (Gibbons et al, 1994). As Kodama and Branscomb (1999) notice, several fast growing economic sectors are situated within the vicinity of science: microelectronics, software, biotechnology, medicine and new materials. These growth areas are dependent on highly skilled people and the findings of the latest research; hence, it should come as no surprise that universities and knowledge creating institutions are perceived as occupying an advantageous position to contribute and to participate in the growth of these so-called science-based industries (Kodama and Branscomb, 1999; Zucker *et al.* 1998; Mowery *et al.,* 2001; Owen-Smith and Powell, 2003)

[1] Which can even be traced back to efforts and experiences situated in the 19th century (see in this respect Hane, 1999; Kodama and Branscomb 1999, Rosenberg and Nelson, 1994).

These observations inspired governments to adopt legislative frameworks that stimulate knowledge transfer from the scientific towards the economical arena. Well known regulations are the Bayh-Dole Act and the Stevenson-Wydler Act in the US (Cohen and Noll, 1994). In Europe, the situation has been somewhat different and still varies significantly across countries (OECD, 2003; Schmiemann and Durvy, 2003, EC 2003a and 2003b). Changes regarding the ownership of intellectual property arising from government-funded research occurred over the nineties[2]. Nowadays, in most European countries an invention generated at a university within the normal course of employment belongs to the university, unless otherwise stipulated in a research contract.[3] Such measures gave a significant boost to the management and governance of IPR-related procedures and policies within universities (Branscomb *et al.*, 1999; OECD, 1999, 2001). Enabling 'entrepreneurial' agency at the level of universities did not only result in the adoption and the further development of IPR-related procedures and policies; but also in the implementation of a variety of transfer-oriented mechanisms. As contract research conducted at universities is more and more considered an inherent part of the mission of today's universities (Branscomb et al. 1999; Etzkowitz and Kemelgor, 1998; Clark, 1998; Mowery *et al.,* 2001), numerous universities have created industrial liaison or technology transfer offices and have become actively involved in the creation of academic spin-offs and joint ventures, science parks and business incubators. Besides engaging in contract research and the creation of academic spin-offs, one of these manifestations of this entrepreneurial orientation is to be found in a growing awareness and activity on the level of patent applications by universities.

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[2] Like in United Kingdom, Belgium and Germany. For a recent exhaustive overview, see Turning Science into Business, OECD (2003).

[3] However, it is only in 2000 and 2001, that the so-called professor privilege has been abandoned in Denmark and in Germany. Danish inventors still keep the right of first refusal. In Sweden and Finland, the professor privilege is still enforced. In the last years, Italian universities have faced the two systems. In 2001, the law changed and assigned title of academic inventions to researchers. Lastly, Italian authorities stepped backward and gave back the ownership of academic IPR to universities.

An increasing number of scholars have analysed the propensity of American universities to patent academic inventions (e.g., Henderson *et al.* 1998; Mowery and Sampat, 2001a and 2001b); Nelson 2001; Sampat *et al.* 2003) but few empirical analyses have been performed in European countries and none at the European level. Most of the investigations performed in the EU have been conducted at lab or institution levels rather than at a national or even EU level.[4] The aim of this paper is to contribute to this literature through a specific analysis of academic patenting activity at European universities. In order to better understand the antecedents of academic patenting activity within European universities, we adopt a resource based perspective (Wernerfelt, 1986; Barney, 1991, 2001) on universities' technological performance and we analyse which resource characteristics of European universities coincide with patent activity. Specific hypotheses have been inspired by the findings of previous studies on academic patenting in the USA and the UK. The analysis reported here builds on an original database obtained by combining the outcomes of a large-scale survey focusing on resource characteristics and entrepreneurial organizational practices of universities, with secondary data sources relating to publications, patent activity and the regional R&D intensity[5].

The paper is structured as follows. Section 2 sets the hypotheses that are to be tested. Section 3 describes the data collection efforts and indicators used. Section 4 describes the empirical model. Section 5 is devoted to the empirical results. Section 6 discusses the main conclusions and their policy implications. Directions for future research are also suggested.

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[4] Eg: Chapple *et al.* (2005) analyse the performance of TTO in the UK. Carayol and Matt (2004) and Carayol (2006) have looked at a large French university. Van Looy and al. (2004) investigate research and entrepreneurial practices in a large Belgian university (KU Leuven), whereas Sapsalis and van Pottelsberghe (2003, 2006) analyse the six major Belgian universities.

[5] Only the universities of the first 15 member countries of the EU are considered.

2. Hypotheses

Following Owen-Smith and Powell (2001) and Powers (2004), who advance a set of institutional characteristics related to the propensity to patent at the university level, we organize our analysis around four central constructs:

- the institutional characteristics of the university;
- the entrepreneurial orientation of the university;
- the research orientation of the university;
- the industrial environment of the university.

Institutional Characteristics

In line with previous researches (Di Gregorio and Shane, 2003; Powers, 2004; O'Shea *et al.*, 2005), the size of the university, as measured by the number of academic staff is expected to be positively correlated with the amount of entrepreneurial activities. Similarly, Carayol, 2006 confirms this result at the laboratory level. At the same time it can be noted that besides size, the portfolio of disciplines present at a university could play a distinctive role. Coupé (2003) and Lach and Schankerman (2003) observed a differential impact of disciplines; the presence of biomedical and engineering faculties being apparently associated with higher levels of patent activity. Sine *et al.* (2003) demonstrate the relevance of the presence of a medical school and the score/ranking of engineering department for explaining the annual account of licenses at universities recognising the important role of these faculties for the development of technology.

H1a: Larger universities have larger patent portfolios.

H1b: Universities with biomedical and engineering faculties have larger patent portfolios.

Entrepreneurial orientation

Previous studies (eg: Siegel *et al.* 1999, 2003a, 2003b, 2004) have underlined the importance of adopting a strategic stance towards the valorisation of research activities. Focusing on three American universities, Bercovitz *et al.* (2001) illustrate how a strategic orientation towards establishing and protecting intellectual property rights affects the development and performance of the technology transfer activities. Debackere (2000) and Debackere and Veugelers (2005) convey a similar message when underscoring the relevance of adopting a strategic orientation towards entrepreneurial activities and translating such orientation into appropriate support structures : universities that intend to "*take advantage of the economic opportunities of their R&D programmes should leverage its innovation potential through appropriate strategies, organisational structures and management processes that allow them to manage part of their R&D portfolio as a business without hampering though the fundamental academic values and activities of research and teaching.*" [Debackere, 2000, p 323]

According to O'Shea *et al.* (2005), this strategic intent of universities is witnessed by the presence and the size of the TTO. Indeed a strategic commitment towards entrepreneurial activities at the level of universities seems to be a necessary condition to establish and develop an appropriate professional support structure which in turn might positively affect the amount and nature of entrepreneurial activities of universities. Empirical evidence for this relationship has been provided by Graff *et al.*(2002) who point out that successful technology transfer is not only dependent on the quality of the research and the involvement of the inventors but also function of the experience of the TTO. Similarly, Chapple *et al.* (2005), analyzing the performance of British TTO's, reveal that the size and experience of the TTO have a positive impact on the amount of entrepreneurial activity. The size of the TTO is also highlighted by Powers (2004) who suggests an impact on the number of awarded licenses. The role of experience was further documented by Mowery *et al.* (2002) and Coupé (2003) who found a positive relationship with the number of patents granted to US universities. Similar observations can be found in the work of Lach and Schankerman (2003) analyzing a panel of 102 American universities over the period 1991-1999.

H2: The size of the technology transfer office is positively related to the size of the patent portfolio.

Scientific research orientation of the university:

Several American studies have identified a positive relationship between scientific capabilities of universities and the amount of entrepreneurial activity (Di Gregorio and Shane, 2003; O'Shea *et al.*, 2005; Murray, 2002). Sine *et al.* (2003) show that the prestige of technical and non-technical research team influences positively the amount of licenses. Lach and Schankerman (2003) find that scientific quality has a positive effect on licensing revenues and on the number of invention disclosures of the faculty involved. Thursby and Thursby (2003) as well as Stephan *et al.* (2006) show that the number of publications is positively related with the number of patent applications. In a similar vein, analyzing the publication behaviour of academic inventors, Gulbrandsen and Smeby (2005), Breschi et al. (2005), Meyer (2006), Goldfarb et al (2006), Van Looy *et al.* (2006) find that inventors publish significantly more, suggesting that the two activities are complementary and reinforce each other. At the level of laboratories at a French research university, Carayol and Matt (2004) and Carayol (2006) come to similar conclusions: highly publishing labs patent more.

Agrawal and Henderson (2001) have analysed the scientific production of some 236 MIT professors and the determinants of their patenting behaviour. The authors conclude that patenting activity is positively correlated with scientific citations. A similar relationship between scientific quality – measured by citations – and patent activity has been observed by Owen-Smith and Powell (2003), Sapsalis *et al.* (2006) and Sapsalis and van Pottelsberghe (2006). They provide evidence that scientific capabilities have a positive and significant impact on the quality of the patent, irrespective whether these patents have been applied for by the academic or the business sector.

Given that a patent is granted for inventions that are novel, inventive and applicable, the positive relationship between scientific performance and patent activity should come as no surprise. At the same time, one could advance the argument that synergies between scientific and patenting activities occur if a university adopts a strategic orientation towards such entrepreneurial activities. Hence, the following hypotheses can be tested:

H3a: A more scientific orientation of universities – as measured by the number of publications per academic staff – coincides with higher levels of patent activity.

H3b: A more scientific orientation of universities – as measured by the number of publications per academic staff – will only manifests itself when a sufficient level of strategic intent towards entrepreneurial activities is present at the level of the university.

Whereas the number of publications per academic staff can be seen as a direct indicator of scientific performance of the university, the yearly amount of contract research can be considered as a complementary indicator signalling the effectiveness of universities to attract external financial resources to conduct research. Moreover, it reflects the degree of interaction with industrial partners and research funding agencies. As such, it could be considered as a proxy of more applied R&D efforts, which might offer more opportunities for the development of technology. Lach and Schankerman (2003) and Chapple *et al.* (2005) find a positive and significant impact of contractual R&D on yearly licensing incomes and on the number of invention disclosures made by American and British universities. Analysing the patenting activities of the French University Louis Pasteur, Carayol (2006) highlights the positive relationship between the amount of private contractual funding and patenting activities at the level of researchers. Larger contract research budgets also signal a broader involvement of academic staff in such activities. Building further on the rationale underlying hypothesis 3b, we will examine to what extent such broader involvement is required to effectuate the strategic intent towards entrepreneurial activities.

H4: The amount of contract research is positively related to the size of the patent portfolio.

H4b: A more strategic orientation of universities towards entrepreneurial activities – as measured by the size of the TTO – will result in more patent activity only if sufficient levels of staff involvement are present (measured by the amount of contract research).

Industrial environment of the university: Regional R&D intensity

Agrawal and Cockburn (2003) have explored a set of hypotheses concerning the relationship between academic and industrial R&D within a region. Focusing on three specific technological fields they found strong evidence of geographic concentration of both university and corporate research. As patents are a tool of technology transfer, one can expect that a university could more easily diffuse new technology in an environment that is active in research: local corporate R&D centres would be a natural market for such universities. Along similar lines, Mansfield (1998) argues that universities are more likely to license technology (one of the aims or expected outcomes of an academic patent) to firms located nearby as the further development of the technology often requires further collaborative efforts (see in this respect also Jenssen & Thursby, 2003). The more research at company levels is taking place within a region, the more university-industry collaborations may blossom and therefore lead to larger patent portfolio for universities (Varga, 1998; Sine et al., 2003; Chapple et al. 2005). In a similar vein, Calderini and Scellato (2005) find evidence of a regional co-localization pattern between scientific and industrial specialization and support that the local presence of a large innovative company positively affects the extent of knowledge spillovers from the academic sector.

H5: Higher levels of regional business R&D intensity will coincide with higher levels of patent activities of universities.

3. Data

Different data sources are combined to test hypotheses H1 to H5. First, we relied on a large-scale survey of universities, launched in 2003-2004. Additional sources of information are the web of science database, the European Patent Office database and the data provided by Eurostat on regional R&D indicators.

The selection of the surveyed universities was based on several criteria. First, selected universities provide educational services in at least one of the following fields: engineering sciences, health sciences or earth and life sciences. This criterion was based on the idea that a university must have a faculty which produces patentable inventions and social sciences and humanities faculties are generally not involved in this type of activity. Therefore, independent arts colleges or business school (Sine *et al.*, 2003) are excluded from the sample. A second selection criterion related to the level of scientific and technological activities. Institutes with some critical mass in terms of publications were identified from rankings provided in the Second Science and Technology Indicators Report (EC, 1997). These rankings contain the most active European research institutions in terms of SCI[6] publication output per country, including top performers for the smaller countries such as Portugal and Greece. To this list, if not yet included, universities were added if they were identified as active in patenting. We relied on EPO patent data – based on whether universities act as assignees - as an additional selection criterion. The survey has been sent to 170 universities around Europe; the data were collected between July 2002 and February 2003. Among them, 105 universities completed the survey yielding a response rate of 61%. For the analysis reported here, data on 87 universities turned out to be useful, the remainder lacking data on certain relevant variables.

[6] Science Citation Index

Besides the survey, other data were retrieved from the Web of Sciences (the total number of SCI publications between 1991 and 2001), the EPO patent database (number of patent applications between 1991 and 2001) and finally Eurostat, from which the figures of the regional business R&D (BERD) intensity were extracted for each university's region. Table 1 summarizes the main variables used for the empirical model. Table 1 summarizes the main indicators used to address the hypotheses and the data sources. Tables A.1 and A.2 in the appendix describe the sample in more detail.

Table 1: Origin of the colleted data and statistics

Data	*Source*	*Year/period*	*Mean*	*St. Deviation*
Academic and scientific staff	Survey	2003	1926	1339
Technology transfer office staff	Survey	2003	9.91	10.61
R&D budget (Millions €)	Survey	2003	28.44	33.99
BERD (% regional GDP)*	Eurostat	1999	1.31	0.91
EPO Patent Applications	Patent Database	1991-2001	13.34	22.9
Number of Publications	Web of Sciences	1991-2001	9257	8846
Presence of disciplines**	Survey	2003	-	-

87 observations

* BERD: Regional Business Expenditure in R&D expressed as % of the regional Gross Domestic Product

** Faculty dummies: 74%, 80%, 85% and 75% of the universities have faculties respectively linked with arts and humanities; engineering sciences; life sciences and health sciences

The survey provided information on the number of academics and scientists in the university, the number of professionals working in a structure aiming to support technology transfer and the size of the R&D budgets obtained by contract research. The latter includes research that result from a contract with a company or a public institution.

Not surprisingly, we observe considerable variation in the size of the universities due to the number of students in the university and the number of disciplines that are available. 50 % of our sample is composed of universities characterised by the presence of a wide range of disciplines while 11% are involved only in engineering or medical sciences.

In Europe, technology transfer activities are still new or recent in a number of universities. Table A.1 shows that while the average size of the TTO equals 10 employees, the 30 smallest TTO employ on average 2.5 full time equivalents. The 17 largest TTOs are composed of an average of 28 full time employees. The dispersion of these figures shows the various extents to which universities are committed towards entrepreneurial activities.[7]

Looking at the R&D budget, a similar heterogeneity appears; some universities attract much more research contracts than others. In 2003, the 16 most active universities in this respect attracted on average 85 millions Euros whereas the average for the total sample amounts to 28.4 million Euros.

To assess the R&D intensity of the region, we used the expenditures in R&D done in 1999 by companies (BERD) expressed as the percentage of the regional Gross Domestic Product. These figures were extracted from Eurostat. For each university, we identified its region and extracted the BERD data at the NUTS level 3 (Nomenclature of territorial units for statistics).[8] Our sample reflects the large diversity of European regions in terms of business expenditures

[7] This is not due to size variation, as similar figures are found when TTO staff per faculty is analyzed.
[8] When available, otherwise BERD at level NUTS 1 or 2 was computed.

on R&D. While the average of this variable in our sample amounts to 1.32%, one observes a minimum with 0.01% of the regional GDP invested by companies in R&D for the region of Calabria (Italy) and a maximum of 4.38% for the region of Stuttgart (Germany).

To measure the level of academic patenting activity, we rely on the number of the patents applied for by the universities at the EPO between 1991 and 2001. The EPO database was preferred to national offices to make a more appropriate comparison of universities. It can be noted that our dependent variable only reflects the patents applied for by the universities and not the amount of patentable or patented inventions by the faculty or academic staff. These last figures could be very different from the first as shown in previous studies (Saragossi and van Pottelsberghe, 2003; Du Plessis *et al.,* 2005; Geuna and Nesta, 2006). As such our dependent variable should be interpreted as a conservative indicator of the patent activity going on at European universities.

The patent portfolio of universities was relatively small during the nineties. This is due to the fact that most European universities started to develop their entrepreneurial orientation in the early nineties. In some universities, internal debates have questioned the role of the university and the protection of academic results has been often challenged by the idea of the open model for sciences. Moreover the different IP-oriented legislations have been enforced in the late nineties. As a consequence, European universities started quite late and slowly to protect their inventions with patent filings (see Sapsalis and van Pottelsberghe, 2003).

The stock of codified knowledge produced and diffused by the universities is approximated by the number of scientific articles written by the scientists of each university. Relying on the Web of Science, the stock of papers published between 1991 and 2001 has been extracted. Table A.1 again indicates a strong variance: on average universities have published 4.80

papers per researcher, whereas in the 21 most "science-oriented" universities, each researcher has published nearly three times more over the 10 years period.

4. Empirical model

The dependent variable is the patenting activity of the European universities, approximated by the number of patent applications filed at the European Patent Office (EPO) between 1991 and 2001. As the distribution is highly skewed, we rely on a negative binomial model (count model) in order to take into account the overdispersion of the data.[9] Individual units y_i follow a Poisson regression model (with parameter λ_i) with an omitted variable u_i such that $\exp(u_i)$ follows a gamma distribution with mean 1 and variance α. The negative binomial model has been estimated with a Quasi-Maximum Likelihood approach.

$$y_i \sim Poisson(\mu_i^*)$$

$$\mu_i^* = \exp(x_i \beta_i + u_i)$$

$$\exp(u_i) \sim Gamma(1/\alpha, 1/\alpha)$$

where β_i is the vector of parameters associated with the vector of explanatory variables $x_{i,}$, Alpha (α) is the overdispersion parameter.

The basic econometric model is described in equation (1) :

$$\hat{\lambda}_i = \exp\left(\beta_1\ AS_i + \beta_2\ TTO_i + \beta_3\ PUB_i + \beta_4\ CR_i + \beta_5\ BERD_i + \sum_{j=1}^{4} \mu_j Fac_{i,j} + C + \varepsilon_i\right) \quad (1)$$

[9] As opposed to the Poisson model, it allows the conditional mean and variance of the dependent variable to be different.

where $\hat{\lambda}_i$ is the estimator of the Poisson parameter explaining the number of EPO patents of each university [i = 1,…, 87] and C is a constant term and ε_i is the error term.

The explanatory variables are *AS*, the number of full time equivalent academic and scientific staff of the university; *TTO*, the number of full time equivalent employees in the TTO; *PUB*, the number of publications per scientific staff; *CR*, the yearly amount of contract research; *BERD*, the regional business expenditure in R&D (expressed as a percentage of the regional GDP); and Fac_j (j = 1..4), 4 dummies representing the fields of Arts and Humanities (AH); Sciences (SCI); Engineering Sciences (ENG) and Medical/Health Sciences (MED).

Equation (1) allows estimating the direct effect of the TTO staff on the size of the patent portfolio of a university. However, as argued when outlining hypothesis 3 and 4, we assume that the interaction between TTO with scientific productivity or contract research could foster patenting activity. To check these hypotheses, the parameter β_2 in the equation (1) can be considered as being composed of a fixed component and a variable component that varies with respect to the scientific productivity (PUB) or with respect to the amount of contract research (CR), as follows (X being equal to PUB or CR):

$$\beta_2 = \beta_{2C} + \beta_{2V} . X_i$$

5. Empirical results

Table 2 presents the results of the different regressions. The column "Model 1" presents the estimated parameters of equation (1). Models 2 and 3 present the estimates of equation (1) with interactions between the TTO variable and scientific orientation (as measured by amount of publications/academic staff) and the amount of contract research (CR), respectively.

Table 2: Empirical results, dependent variable: Total number of patent EPO application 1991-2001

	Model 1		*Model 2*		*Model 3*	
Dependent Variable	B	St. Dev	b	St. Dev.	b	St. Dev.
Main Effects						
Academic staff (AS)	3.4E-4***	8.66E-5	3.88E-4***	9.15E-5	3.5E-4***	8.56E-5
TTO staff (TTO)	0.016*	0.010	-0.018	0.018	-0.006	0.016
Publication per staff (PUB)	0.091**	0.036	0.006	0.049	0.086**	0.038
Contract research (CR)	9.2E-9***	3.11E-9	9.99E-9***	3.05E-9	3.49E-9	4.23E-9
BERD	-0.020	0.155	-0.059	0.161	-0.018	0.155
Interaction Effects						
TTO*PUB			6.21E-3**	2.63E-3		
TTO*CR					7.6E-10**	3.95E-10
Faculty dummies						
AH	-0.448	0.342	-0.518	0.339	-0.393	0.343
MED	0.932***	0.311	0.793**	0.318	0.845***	0.315
ENG	0.814***	0.316	0.689**	0.323	0.829***	0.324
SCIEN	0.026	0.412	0.057	0.410	-0.008	0.409
Const	-0.696	0.542	-0.080	0.622	-0.511	0.554
# Obs.	87		87		87	
Pseudo-R^2	0.098		0.098		0.095	
Log Likelihood	-285		-285		-286	

Sources: Survey; Web of Sciences(1991-2001); Eurostat (1999), EPO database (1991-2001)

Significance levels: * <10%; **< 5%; *** < 1%

The results broadly confirm the hypotheses regarding universities' characteristics and their patenting performances. The size of a university, as measured by the number of scientific staff, is significantly and positively related to the stock of patent applications. This clearly suggests that size is an element that positively affects the capacity of a university to develop a large patent portfolio. These results are in accordance with the literature and confirm hypothesis H1a: the larger a university, the larger is its patent portfolio. A positive effect is also associated with the dummy variables representing the presence of engineering and/or health sciences faculties. These results confirm hypothesis H1b: universities with biomedical and engineering faculties have larger patent portfolios.

Table 2 (column 1) shows that the number of staff involved in the technology transfer office relates positively to the stock of patent applications. This result, although only significant at 10 per cent probability threshold, suggests that the commitment of universities towards entrepreneurial activities plays a role in the development of larger patent portfolios, which corroborates hypothesis 2.

The first column of Table 2 also reveals that the number of patent applications correlates positively with the scientific productivity (PUB) of academic staff and the amount of contract research (CR). These findings are in line with hypotheses 3 and 4. They confirm the importance of research activities for patenting activity at universities. These measures witness the involvement of the academic researchers in research projects of quality as well as an entrepreneurial commitment of these researchers by being involved in project-oriented researches.

Finally, there is no significant relationship between the regional business R&D intensity and the number of academic patents filed by a university. Compared to resource characteristics of universities – size, disciplines, scientific productivity – variation in terms of R&D intensity of the regional business texture does not coincide with variation in terms of patent portfolios. While one could be inclined to conclude that the local R&D markets do not affect ‘technology supply’ dynamics at the level of universities, one important caveat seems relevant. As explained in the data section, academic patenting in Europe does not automatically translate into universities acting as patent applicant. To the extent that the transfer of academic inventions towards companies with local presence is more prevalent, a positive relationship between the total patent activity of universities and the R&D intensity of the regional business texture could become observed when these patents would been drawn into the equation.

Models 2 and 3 in table 2 aim at testing whether interactions occur between the entrepreneurial orientation of a university – measured by the size of the TTO - on the one hand and the scientific productivity and the amount of contract research on the other hand. The results reported in column (2) suggest a strong combined effect of entrepreneurial orientation and scientific productivity on patenting activity. The two parameters associated with the main effects (TTO and PUB) become non significant. In other words, enlarging the TTO without a certain level of scientific productivity being present, will not result in an increase in patent applications. And vice versa, higher levels of scientific productivity without a properly developed TTO would not result in higher levels of patent applications. Similar results are observed regarding the interaction effect between the amount of contract research and the size of the TTO in column 3. Higher levels of patent activity coincide with the simultaneous presence of an entrepreneurial orientation at the level of the top of the university (as measured by the size of the TTO) and larger proportions of the academic staff involved in contract research (as measured by the total amount of contract research).

6. Conclusions

This paper attempts to better understand the resource characteristics coinciding with patent activity at European universities. The empirical analysis relies on a large scale survey of 87

European universities complemented with secondary data sources. The results broadly confirm the existing findings: what determines the size of a university's patent portfolio is mainly related to the intrinsic characteristics of the university and less to its regional environment.

The most important antecedents of academic patenting are the size of the academic staff, its scientific productivity and the amount of contract research. In addition, the presence of biomedical and engineering faculties coincides with higher levels of patent activity. The size of the TTO, considered as an indicator of the entrepreneurial orientation of universities, is also associated with a larger patent portfolio. There seems to be no direct impact of the regional environment on the patenting activity of the universities. At the same time, it can be argued that in research-intensive regions, it is easier to find a research partner and initiate research collaborations. Previous research has indicated that a considerable amount of patent activity of European academics implies a transfer of ownership rights to the industrial partner. This phenomenon might explain the absence of the relationship between both variables within this study. In addition, when it comes to licensing and patenting activity, the region of reference is the world, not the local region.

Finally, the most interesting findings were obtained with respect to the combined effects of several key variables. Our findings suggest that in order for a strategic orientation of a university towards technology transfer to be effective, sufficient levels of scientific productivity need to be present. Also the opposite holds true: the presence of scientific capabilities needs to be coupled to a strategic commitment towards technology transfer in order to yield results in terms of patent activity. Higher levels of patent activity are observed in universities that simultaneously adopt a scientific and an entrepreneurial orientation.

Similar observations can be made in relation to the combined effect of the size of the TTO and the amount of contract research. Whereas the first constructs can be seen as reflecting the commitment of the top, the amount of contract research will be higher when more academic staff is willing to engage in additional research activities, supported by companies and funding agencies. Our findings again suggest that both elements need to be present to result in higher levels of patent activity at universities. Higher levels of patent activity are observed within universities characterised by both a strategic commitment towards technology transfer and the presence of a receptive attitude among academic staff towards contract research.

We started this paper with outlining dynamics related to the role of universities in today's knowledge economies. A more entrepreneurial orientation of universities is being advanced as important for innovation systems to be effective, especially within new emerging fields of economical activity. The findings of this paper add to the ongoing debate on the role of universities in different ways. First, we offer an empirical insight into the antecedents of technological performance of universities on a European level. Second, our findings suggest that focusing on technology transfer arrangements solely might not be sufficient. Only to the extent that scientific capabilities are present, higher levels of technology activity are being observed. So, if one wants to observe a more active participation of European universities in technology development, strengthening the research capabilities of European universities seems to be as relevant as further professionalizing their technology transfer practices. Indeed, combining a scientific with an entrepreneurial orientation of the university as a whole coincides with higher levels of technology activity, suggesting a distinctive role of universities in innovation systems.

Our findings also introduce several suggestions for further research. As mentioned, patent activity of academic staff does not always imply that universities act as assignees. Further research should investigate to what extent academic technology activity - transferred to industry - might be different in nature, and hence different in terms of organizational antecedents. Moreover, the data analyzed here shows considerable variance. Given the limited set of variables and the size of the sample, further research efforts for refining and extending our observations seem highly appropriate. Such future research on the European level might pay specific attention to the role of institutional framework conditions, which still differ widely in Europe: do differences in technology performance of universities also coincide with differences in institutional characteristics of national innovation systems? It goes without saying that differences regarding the role of universities in society - including the legislative framework conditions adopted with respect to the nature of entrepreneurial agency at the level of universities - deserve our attention in this respect. While fragmented evidence on the distinctive role of such institutional framework conditions is becoming available, a large scale empirical assessment of its impact on performance – both in terms of scientific and entrepreneurial performance - across Europe is still missing. Recent changes in related policies across Europe further underscore the relevancy of follow up research aimed at analyzing constituents and consequences of universities' entrepreneurial performance.

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8. Appendix

Table A. 1: Distribution of the university characteristics within categories.

Data	*Subcat 1*		*Subcat 2*		*Subcat 3*		*Total set*	
	Obs.	*Average*	*Obs.*	*Average*	*Obs.*	*Average*	*Median*	*Average*
Academic and scientific staff	31	708	35	1632	21	4765	1611	1926
TTO staff	30	2.4	40	17	17	27.8	6	9.91
R&D budget (Millions €)	34	6.22	37	21.1	16	85	17	28.4
BERD (% regional GDP)	29	0.4	33	0.99	25	3.66	1.02	1.31
EPO Patent Applications	27	0.4	45	10.1	15	44	5	13.3
Number of Publications	34	2303	32	6834	21	27228	7009	9257
Publications per staff	31	1.62	34	4.08	22	11.85	4.50	4.80

87 Observations

Subcategory 1 regroups the observations with the lowest value for the analysed characteristic (< mean minus ½ standard deviation).

Subcategory 2 regroups the observations with the middle values for the analysed characteristic (range between average and plus/minus ½ standard deviation).

Subcategory 3 regroups the observations with the highest values for the analysed characteristic (> mean plus ½ standard deviation).

Table A. 2: Presence of disciplines within the sample

	Presence of faculties
Arts and Humanities Faculties	75%
Medical School	74%
Engineering School	81%
Life and Earth Sciences Faculties	80%
Complete University (all aforementioned categories)	48%
Engineering/Medical School	11%

87 Observations